THE ORTHOPAEDIC FORUM

The Future of Orthopaedic Information Management

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Not long ago, if you were reading an article of this type, it was safe to assume that you were holding a printed journal. Today, while some readers might have a document in hand, many are sitting in front of a computer monitor, and still others are reading on a smartphone, tablet, or other wireless device. Accordingly, as paper is replaced by pixels, readers around the world can readily access their reading material at the point of need. Yet this foray into the digital domain does not represent unalloyed progress: the Internet has provided everyone with a printing press, allowing experts, quacks, and all those in between the ability to publish medical material with at least a veneer of authority. Thus, the challenge for the consumer is not so much to find some medical information, but to find valid, trusted, and pertinent medical information[1].

This challenge is especially daunting, given the size of the World Wide Web. For example, a keyword search of "carpal tunnel syndrome" in PubMed returns less than 8000 entries (as of October 2011), whereas the same search in Google finds more than 12.3 million results. Beredjiklian et al.[2] evaluated the quality of information regarding carpal tunnel syndrome on the Internet and found that 23% of web sites offered unconventional or misleading information, and the mean informational value of the web sites was 28.4 of a possible 100 points. Likewise, Labovitch et al.[3] examined Internet sources regarding minimally invasive hip arthroplasty and found information that was often "misleading and of poor quality."

In response, new models for obtaining information have been created. Web sites of well-respected organizations such as the American Academy of Orthopaedic Surgeons (AAOS) aggregate material and post commentaries. Web 2.0 technologies[4], including forums, blogs, and social networks, allow surgeons to comment on orthopaedic issues and modulate understanding accordingly. Search engines that not only find but sort information according to unspoken and idiosyncratic algorithms are increasingly important as well.

In short, the task of information management faces new imperatives and may avail itself of new tools. As the Internet grows, we may see a great transformation of how information is produced, gathered, and used. In this review, we outline our forecasts regarding the contours of the emerging medical information landscape.

New Forms of Interpretation: Crowd Intelligence

In 1907, Francis Galton observed that the weight of an ox was estimated poorly by individuals in a contest at a country fair, yet the mean of these guesses was within 99.2% of the true value—a collective estimate that was more accurate than the estimates given by cattle experts[5]. From that observation, it was recognized that the aggregation of information from groups of perhaps ordinary people, so-called crowd intelligence, might yield better decisions than could have been offered by individual experts.

In its most basic form relating to medical papers, crowd intelligence may be used to catch manuscript errors that eluded detection in the peer review process. Just as multiple readers of a radiograph may help to avoid clinical errors, group commentary may help pick up mistakes in papers that would otherwise

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be missed. Undetected errors may be a bigger problem than we realize. Emerson et al.[6] reported an elegant experiment examining the behavior of 210 orthopaedic surgery reviewers (including a large sample from *The Journal of Bone and Joint Surgery*) who were sent a contrived manuscript. The average reviewer in the study found less than one of the seven known errors.

Crowd intelligence can go beyond asking explicit questions of a group. Even tacitly collected information can prove useful. For example, it was reported in *Nature* that the onset of a flu epidemic is heralded by an increased frequency of searches on Google for flu remedies[7]. Similarly, in the near future, it might be possible to infer problems with a specific arthroplasty prosthesis by detecting interest in case reports describing early failure or the like.

With the simple communication tools of the Internet, readers all over the world can participate in a "journal crowd," a virtual journal club in which consensus is reached over the meaning, significance, and context of a paper. Ultimately, crowdsourcing may spur the evolution of the format of scientific reports. For example, the prototypical discussion section of the paper could be written by the readers as commentary on the methods and results sections. After all, it is not necessarily the case that the best interpretation of data can be offered by the source of the data. In fact, fealty to the hypotheses that motivated the collection of the data in the first place may render the experimenter too biased to comment fairly. Thus, while not all crowds are intelligent, the interpretation offered by a large group of reasonably wise readers may be more valuable than the insights of a lone brilliant scholar or two who may be hampered by cognitive biases[8].

New Forms of Texts and Journals: Internet-Based Publishing

Although online publications can maximize content with use of videos, links, and supplemental materials (and minimize heft), there are still some advantages to traditional print media. Printed material can be read in venues without access to electric power or wireless signals. Additionally, as noted by Shafer[9], "the attention given to typeface, letter-spacing, line-length, leading, page size, and margins, and all of the other tricks [of typography], gives the eyes and the brain an edge [with paper] over copy published for Web browsers." As such, we expect paper journals to endure. Perhaps the niche for paper lies in short pieces (such as the "In Brief"[10] articles introduced in *Clinical Orthopaedics and Related Research*), which can be printed on a single sheet and saved for later reading in venues less hospitable to electronic media.

We also predict that the use of hyperlinks will change the style of scientific writing, allowing authors to compose more tersely. With these links, an author can expand on a concept selectively (i.e., for only the users who wish to follow the link). Authors will also be able to embed code within their text that will enable a computer to understand the nature of the information. This process of so-called semantic tagging will enable search programs to get "the concepts right instead of relying on the vagaries of wording," as noted by Kent Anderson[11], the CEO/Publisher of JBJS.

Electronic publishing of textbooks will improve them. Hardcopy printing is hindered by its lengthy revision cycle and the ponderous mass of most textbooks. For example, the current printed edition of *Campbell's Operative Orthopaedics*, published in 2007, weighs more than thirty-eight pounds. Some of the Internet sources vying to replace traditional reference textbooks are shown in Table I. On the conservative end of the continuum are the sources that follow traditional approaches, but with online features. On the more radical end lies the wiki-based collaborative authoring model, exemplified by Wikipedia: free, crowdsourced content that is open to continuous revision. Neither is perfect, as the first model does not avail itself of crowdsourcing, whereas the second may be insufficiently authoritative. For example, although Wikipedia was found to be reasonably accurate in some orthopaedic surgery domains (e.g., osteosarcoma[12]), in general, unsigned articles (e.g., Wikipedia pages) should not be the basis of treatment for our patients.

A hybrid of the two models, such as Orthopaedia.com[13], may turn out to be most useful. Orthopaedia is a crowdsourced repository of information that is open to continuous revision, but maintained by a closed community of identified contributors. The success of closed-community wikis in orthopaedic surgery is hardly ensured, however, as in most online communities, less than 1% of the users contribute substantially. Applied to the fairly small orthopaedic surgery community, this rule implies that Orthopaedia might not corral enough contributors to succeed. The success of closed-community wikis may thus depend on the development of new forms of social credit, motivating members to contribute at rates higher than currently seen in most online communities.

Many medical journals will also change significantly. William Curtis, President, Springer Science+Business Media, has noted that the "uptake of Internet versions of long-established print journals has been so widespread that increasingly the print editions can be eliminated. . .only a handful of print editions will exist a decade from now, if not sooner."[14] The appeal of the web is obvious: although the editorial costs for electronic journals can be comparable to those of traditional paper journals, the marginal distribution cost of electronic copies approaches zero. Furthermore, unlike a traditional journal, an online journal can publish an arbitrarily large number of papers of arbitrary length.

With the migration to the web, the concept of "reading a journal" may change, as readers may create their own composite journals by merging electronically accessed articles into a self-created personal interest publication. For example, a reader may use Really Simple Syndication (RSS) feeds to create an electronic table of contents limited to only articles of interest (Fig. 1) or from an automated PubMed search[15].

Web-based publishing will affect the content of what is written. With the volume limit lifted, authors may be requested or compelled to post raw data. For instance, authors wishing to describe a cohort of patients undergoing hip arthroplasty in a

TABLE I Internet Sources for Orthopaedic Reference Information

Resource	User Revisable Content	Crowdsourcing	Peer Review	Authorship	Price	Advertising on Site
Wikipedia (www.wikipedia.com)	Yes	All	Possible, but anonymous	Anonymous	Free	No
Orthopaedia – Collaborative Orthopaedic Knowledgebase (www.orthopaedia.com)	Yes	Members	Possible, but identified	Author designated	Free	No
Medscape Reference (eMedicine) (emedicine.medscape.com/orthopedic_surgery)	No	None	No	Author designated	Sign-up required	Yes
Wheeless' Textbook of Orthopaedics (www.wheelessonline.com)	No	None	No	Author designated	Free	Yes
Orthopaedic Knowledge Online (orthoportal.aaos.org/oko)	No	None	Unknown	Author designated	Subscription (AAOS dues)	No
ORTHOSuperSite (www.orthosupersite.com)	No	None	Partial	Author designated	Sign-up required	Yes
UpToDate (www.uptodate.com)	No	None	Anonymous	Author designated	Subscription	No

paper journal would be forced to select the data of interest. However, in a web-based model, authors may post the complete dataset for every patient. To be sure, unfiltered publication of information alone in the name of research is not desirable, and many readers will be unable to draw reliable conclusions from raw data. Nonetheless, comprehensive data reporting, as a supplement to a fully described study, will be particularly useful for those performing meta-analyses and therefore will ultimately benefit the average reader.

In a journal where space is not a concern, peer reviewers might be instructed to ignore the question of whether an article is of interest to the readership and consider only whether the study is valid and potentially interesting to even one reader. This mirrors the "long-tail" business model in which some Internet-based commercial firms profit from selling small volumes of less popular items to many customers[16]. When only validity (and not potential reader interest) is considered, it is more likely that studies in which no differences between groups are found (i.e., studies thought to be less interesting to readers) will appear more frequently in medical journals. The increased incidence of "negative studies" also abets the performance of meta-analyses. Growth in pay-per-view reimbursement schemes for journals, in which payment is rendered every time materials are downloaded, will also motivate a journal to produce the maximal amount of source content. Granted, a long-tail approach to peer review necessarily implies that publication in a once-exclusive journal might lose its cachet, but new forms of identifying merit (i.e., supplanting the current mode which

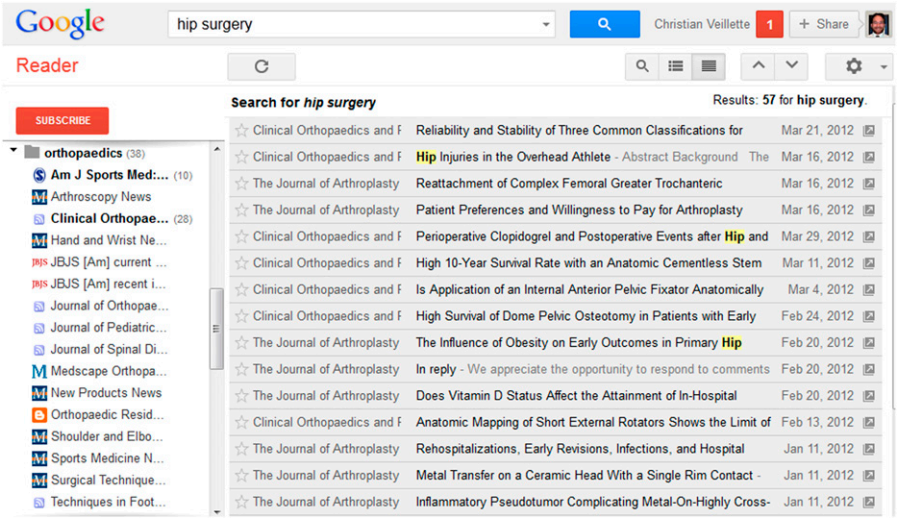

Fig. 1

A screenshot of a Google Reader table of contents for ''hip surgery'' articles from the RSS feeds distributed by *Clinical Orthopaedics and Related Research* and *The Journal of Arthroplasty*.

rests in large part on impressing editors and reviewers) are apt to emerge.

The strongest countervailing force against unfettered expansion of journals is the effect such growth may have on a journal's "impact factor." The impact factor is a rating metric derived by the ratio of citations to the journal in a given year divided by the number of items the journal published in the previous two years. Clearly, publishing items that are not cited frequently will diminish the impact factor. In the coming years, we predict that the impact factor will matter less: "times cited" will give way to more nuanced measures of readership and influence. Additionally, with search engines effectively turning the pages for them, readers will be oblivious to the fact that many uninteresting things were published. In the transition, when publishers heed both impact factor and usage rates, we may see the proliferation of "sister journals" spun off the main publication. For example, the JBJS Case Connector allows *The Journal* to offer access to case reports that are not apt to be cited often, without diluting the main journal's impact factor.

New Forms of Authorship: Social Media

Because science is socially constructed[17]—what is scientifically true is what the community of scientists says is true—the changes in medical information processing may be strongly affected by social change. That is, the Internet's potential to upend hierarchies[18] will itself change how medical information is generated, evaluated, and used.

The fundamental change brought about by Internet-based publication is that all readers are now potential writers. Of course, giving a publishing tool to ignorant people makes them an authority as much as giving them a scalpel makes them a surgeon. In addition, Internet writers may be more than ignorant; they may be deliberately deceptive[19]. Therefore, more than ever, readers must read with caution. Without an authority doling out credentials, the need for a means to ascribe credibility must be established.

Recognized medical organizations (e.g., the AAOS) may be called on to certify the Internet identity of individuals, and in turn, by maintaining a record of this individual's activity, allow the person to develop a web reputation based on this activity and the feedback from users. At present, a surgeon's academic reputation is based on the papers written, lectures given, and leadership positions held, among others. An "Activity Log" maintained on Orthopaedia, for example, can document all that and more. This log can record not only original publications, but also what one has read, what one has said in commentary, and what others have said about those comments. Cited activities in the log can also include social connections and search queries. These data can be used to calculate the extent and value of online participation and grant so-called community equity to the participant[20].

This type of activity log might help motivate users to participate. If users were to get positive reputational credit for an action (such as reporting an error in a manuscript), it is more likely that users will take that action. Another motivation may come from the need to document lifelong learning for board recertification. We suggest that the activity log could be used to demonstrate attainment in the realm of "performance in practice"[21], or other areas necessary for professional credentialing.

Conclusions

The face of medical information is changing and will continue to change. This change is coming chiefly because the new medium of consumption is also a medium of production. When users read on electronic devices, entirely new realms of data will be, quite literally, at hand (namely, the data produced by readers in response to primary material, the responses to those data, supplementary materials, etc.). Within that stream will lie gold, in the form of a flow of new and worthwhile information. For example, if there are 12.3 million web pages on carpal tunnel syndrome, and 77% of them are free of unconventional or misleading material, there are approximately 9.5 million potentially useful pages. More than ever, the challenge to users will be to sift through the stream, keeping the valuable and discarding the rest. To help with that task, new entities will arise, established entities will adapt or die, and new modes of social credit will emerge.

Variations on Wikipedia (exemplifying collaborative composition) and Facebook (representing the world of social networks), modified for the medical domain, may obliterate traditional methods of knowledge dissemination. Thus, the potential looms for a more egalitarian and useful web of knowledge. However, there is also the prospect of squandered opportunity. Because patients are helped by any step that enhances the quality of medical evidence or the process of evaluating it[22], the orthopaedic community must strive to create the optimal future for orthopaedic information management.

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References

1. Clough JF, Veillette CJ. Orthopaedic Web Links (OWL): a way to find professional orthopaedic information on the internet. Clin Orthop Relat Res. 2011 Jul;469(7):2049-61. Epub 2011 Apr 1.

2. Beredjiklian PK, Bozentka DJ, Steinberg DR, Bernstein J. Evaluating the source and content of orthopaedic information on the Internet. The case of carpal tunnel syndrome. J Bone Joint Surg Am. 2000 Nov;82-A(11):1540-3.

3. Labovitch RS, Bozic KJ, Hansen E. An evaluation of information available on the internet regarding minimally invasive hip arthroplasty. J Arthroplasty. 2006 Jan;21(1):1-5.

4. Eysenbach G. Medicine 2.0: social networking, collaboration, participation, apomediation, and openness. J Med Internet Res. 2008 Aug 25;10(3):e22.

5. Galton F. Vox populi. Nature. 1907;75:450-1.

6. Emerson GB, Warme WJ, Wolf FM, Heckman JD, Brand RA, Leopold SS. Testing for the presence of positive-outcome bias in peer review: a randomized controlled trial. Arch Intern Med. 2010 Nov 22;170(21):1934-9.

7. Ginsberg J, Mohebbi MH, Patel RS, Brammer L, Smolinski MS, Brilliant L. Detecting influenza epidemics using search engine query data. Nature. 2009 Feb 19; 457(7232):1012-4.

8. Kahneman D. Thinking, fast and slow. New York: Farrar, Straus and Giroux; 2011. p 499.

9. Shafer J. Print vs. online: the ways in which old-fashioned newspapers still trump online newspapers. Slate. http://www.slate.com/id/2302014. Accessed 2012 Jan 8.

10. Brand RA. ''In brief'' articles. Clin Orthop Relat Res. 2009;468(3):913.

11. Anderson K. Going semantic — diving headfirst into the deep end of the content pool. 2011 Jun 1. http://scholarlykitchen.sspnet.org/2011/06/01/going-semantic-testing-the-limits-of-a-promising-approach-to-content/. Accessed 2011 Aug 8.

12. Leithner A, Maurer-Ertl W, Glehr M, Friesenbichler J, Leithner K, Windhager R. Wikipedia and osteosarcoma: a trustworthy patients' information? J Am Med Inform Assoc. 2010 Jul-Aug;17(4):373-4.

13. Orthopaedia: collaborative orthopaedic knowledgebase. www.orthopaedia.com. Accessed 2011 Aug 8.

14. Curtis W. The internet effect on medical journals. http://www.orthopaedia.com/x/rgDVB. Accessed 2011 Aug 24.

15. PubMed. Saving searches as RSS (Really Simple Syndication) feeds. http://www.ncbi.nlm.nih.gov/books/NBK3827/#pubmedhelp.FAQs. Accessed 2011 Aug 24.

16. Anderson C. The long tail from smartercomics: why the future of business is selling less of more. Mundelein, IL: Writers of the Round Table Press; 2011.

17. Kuhn TS. The structure of scientific revolutions. Chicago: University of Chicago Press; 1962. p 172.

18. Deshpande A, Jadad AR. Trying to measure the quality of health information on the internet: is it time to move on? J Rheumatol. 2009 Jan;36(1):1-3.

19. Ott M, Choi Y, Cardie C, Hancock JT. Finding deceptive opinion spam by any stretch of the imagination. Presented at the 49th Annual Meeting of the Association for Computational Linguistics; 2011 Jun 19-24; Portland OR.

20. Reiser PH, Diamond P. Method and system for tracking social capital. US patent number 8010902. Issue date: 2011 Aug 30.

21. Ezaki M. Maintenance of certification and self-assessment examinations. J Am Acad Orthop Surg. 2011 Apr;19(4):185-6.

22. Bernstein J. Evidence-based medicine. J Am Acad Orthop Surg. 2004 Mar-Apr; 12(2):80-8.